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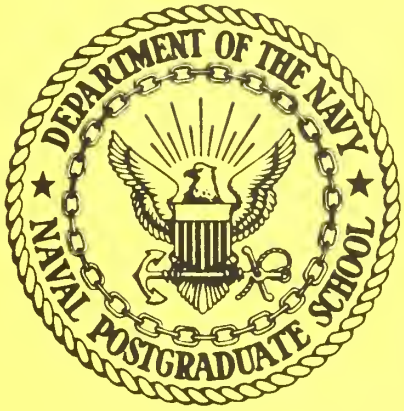

A NAVIGATION MICROCOMPUTER AND
SHIPBOARD INFORMATION DISTRIBUTION

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A program to calculate position from three celestial sightings has been written in BASIC. It is suggested that the program be implemented on a microcomputer configured as a navigation calculator. An extension of the idea of the distribution of the result would be an integrated navigation system.

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1. Introduction

Modern advances in electronics offer a potential improvement in the implementation of shipboard information handling and calculations. This report summarizes some recent work at the Naval Postgraduate School which contributes to the solution of some of the design problems.

The recent maturation in industrial usage of digital techniques for information distribution and control is culminating in the incorporation of microcomputers in instruments and the adoption of common interface specifications to allow interconnection of laboratory electronic devices in a manner somewhat similar to the input-output bus schemes of digital computers. Dedicated and interconnected microcomputers can also be effectively employed aboard ships.

Microcomputers are inexpensive, miniaturized systems composed of a small number of integrated circuits. Presently available circuits allow configuration of computers whose processing capabilities are somewhat limited, but whose price and power requirements are low enough to make it feasible to dedicate microcomputers to special purposes. Section 2.2 of this report discusses an investigation into microcomputer implementation of one application area,

celestial navigational calculations.

The design of an efficient system for distribution of information to the appropriate points on the ship is just as important as the design of the calculator. Section 2.3 summarizes some relevant information.

Consideration of practical aspects of the shipboard use of the navigation microcomputer led to a discussion of an information distribution system for this and other devices. While the work summarized in this report includes recognition of the desirability of such an integration of information, no detailed problem analysis or algorithms for such a task are provided here. Further work appears worthwhile, based on the ideas of information processing and distribution covered in the following.

2. Navigation calculations and information distribution

A computational task which still faces the modern seafarer is to calculate a fix from sightings of celestial objects. The calculation is only moderately complicated, self-contained and representative of many necessary to the operation of a ship system.

Automatic systems and semiautomatic celestial navigation systems for submarines and aircraft have been implemented. This section deals with considerations, mostly relevant to surface ships, for performing the celestial fix calculations and distributing throughout the ship information such as the

results of this calculation.

2.1. Hand calculators

To the general public, the most noticable effect of recent advances in the state of the art of large-scale integration has been the appearance of a wide range of calculators. These calculators range from pocket-size adding machines to desk-sized machines with hardcopy and offline storage peripherals. The basic organization of these calculators is designed for the electronic execution of individual, manually directed steps of calculations. Advanced models extend the "electronic slide rule" approach by allowing storage and execution of sequences of keystroke operations. Some of these programmable calculators even allow entry of programs in languages such as BASIC or APL. Nonetheless, each of the programmable calculators is a specialized device with more restricted capabilities and less flexibility than a general-purpose microcomputer.

The calculation of position from celestial sightings is complicated enough to require the use of a previously developed program. The Hewlett-Packard HP-65 is a hand-held, programmable calculator with magnetic cards for off-line storage and retrieval of programs. A sizable number of short programs for marine navigation are available for this limited-memory device. Some have been developed by users, and some comprise the manufacturer's "Navigation Pac" [1]. Workers at NELC have elaborated on the usage of such

machines for celestial navigation. The use of such a machine to calculate a fix from star sights presently requires changing program cards by hand.

2.2. Navigation microcomputer

A recent NPS thesis [4] examined the problem of implementation of, and the subsequent distribution of results of, navigational calculations. The emphasis there was on algorithms for the solution of the celestial fix problem.

The fix algorithm was implemented in the BASIC language, partially in order to allow machine independence. It provides the calculation of a three-star fix without requiring the operator to enter data from tables. When implemented on a microcomputer-based system in the fashion planned at NPS, the internal numerical precision should be one part in four billion.

The thesis also suggests a self-contained celestial navigation microcomputer with problem-oriented input and output. In contrast to the HP-65 approach, the device envisioned in the thesis would not require manual operation of program cards, would use a conventional data format, would be expandable, would be less susceptible to pilferage and loss, and would provide a natural means of input and output. It would include a printed output for record purposes.

2.3. Information distribution

A potential direction for future work assumes multiple sources of information and an efficient information distribution system. It should be possible with this basis to provide processing which inter-relates the multiple information sources, rather than merely transferring the information. For example, one ship may have many sources of information of potential use to the navigator. At times, one electronic subsystem such as a satellite navigation receiver may be the most accurate information source. At other times, a better fix may be obtainable by interpolation among the results of several radio sensors such as OMEGA and celestial sightings. In extreme cases and as backup verification of the others, it may be appropriate to use traditional depth sensor, pit log and dead reckoning. An integrated navigation system such as sketched in Reference [3] could monitor all of these information sources; emphasize each according to its inherent accuracy, its degree of self-consistency, comparisons among various sources or external user instructions; and automatically provide a system-wide best estimate of position.

A central processing system was suggested for monitoring diverse terminals, collecting the inputs from several subsystems, extracting the best information from the combined data, and distributing the results to the appropriate users.

Although Ref.[4] does not address specific design details of such a distribution system, other work has. Another recent

NPS master's thesis has considered the implementation of ship-wide distribution of information, excluding speech [5]. This independent investigation of the application of current digital electronics concludes that the implementation in new ships of port-and-starboard redundant all-digital information bussing would result in a system which is more easily expandable, cheaper and more reliable than present point to point, multiple conductor cabling.

Most recently, another student investigated design problems of computer data links via fiber optics [2]. He configured and tested a linkage between two microcomputer systems. Potential advantages of optical links include large bandwidth, electrical isolation and physical characteristics which are in some ways superior to wire.

3. Summary

The work described in Section 2 has laid the groundwork for prototype implementation of a navigation microcomputer. Although the programs have not yet run on the development microcomputer system (pending a review and possible redesign of the current BASIC facility), they have been run on the local computing center facility, establishing a degree of soundness.

The desirability of implementing an integration of several navigational information sources has been formulated as part of the overall ship system information distribution problem.

The language BASIC was selected for implementation of the celestial fix program primarily because of the high precision attainable. Although the language has deficiencies with respect to software design principles (such as the lack of variable scope and the limited set of identifiers), its capabilities are proved sufficient for the problem. Implementation with another popular microcomputer language, PL/M, should be possible, but was rejected because of the lack of convenient execution of high-precision arithmetic. A third possibility is ML80 [6]. Both PL/M and ML80 are basically system programming languages for particular (Intel) microprocessors; while PL/M runs on a large machine to produce object code for a microcomputer (is a cross-compiler), ML80 exists in a form which runs on the microcomputer development system itself (is resident). One of these latter two languages is probably appropriate for implementation of the main control framework of an integrating information system. Application programs such as the celestial fix programs may continue to be best written in a language such as BASIC.

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